The NMX demonstrator and its electronics developed in BrightnESS

Michael Lupberger (CERN), Dorothea Pfeiffer (ESS)

IKON15, Lund, 11.09.2018

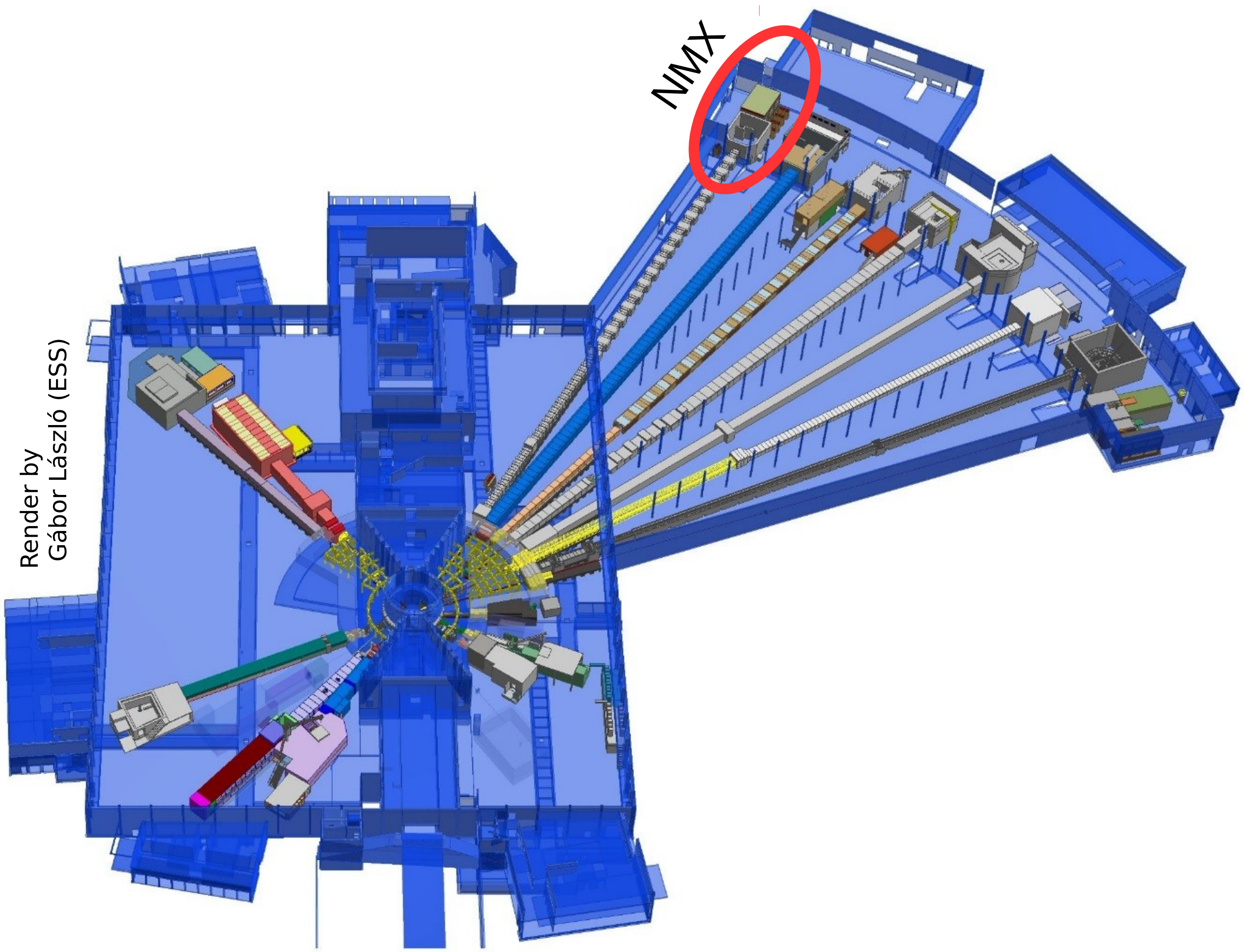
Material of presentation from: R. Hall-Wilton,Z. Kraujalyte, M. Lupberger, D. Pfeiffer, P. Thuiner, *Module for NMX Detector*, BrightnESS Deliverable Report: D4.13 (2018)

and M. Lupberger and P. Thuiner, DT Training Seminar – CERN – 15.02.2018

Outline

- NMX - overview
- BrightnESS at CERN: NMX demonstrator
  - Detector
  - Electronics
- Test beam at Wigner institute
- Conclusion and outlook

Overview: The NMX instrument at ESS



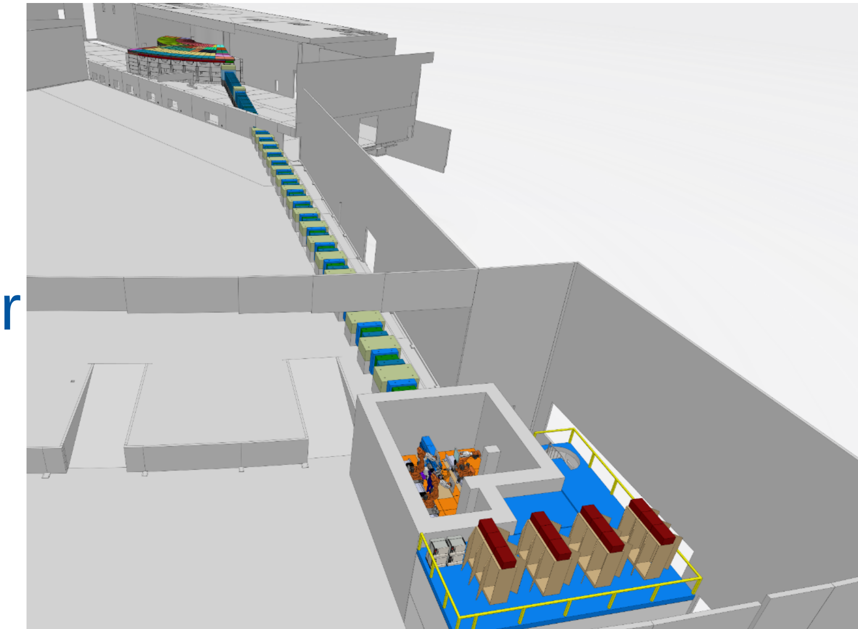
Overview: The NMX instrument at ESS

Structure determination of biological macromolecules by crystallography

Locates hydrogen atoms relevant for the function of the macromolecule

Needed: high rate capabilities, good detection efficiency, position & time resolution

Physics demonstrator build at CERN GDD lab as part of BrightnESS project within Horizon 2020



Illustrations taken from https://europeanspallationsource.se/

Who: People in BrightnESS WP4.1 at CERN

Dorothea Pfeiffer
ESS Staff from Sept. 2013
Software development for
μ-TPC, simulation,
coordination with WP 5.1

Patrik Thuiner
CERN Fellow from Feb. 2016
Detector construction: GEMs,
Gadolinium cathode, design&
optimisation for scattering

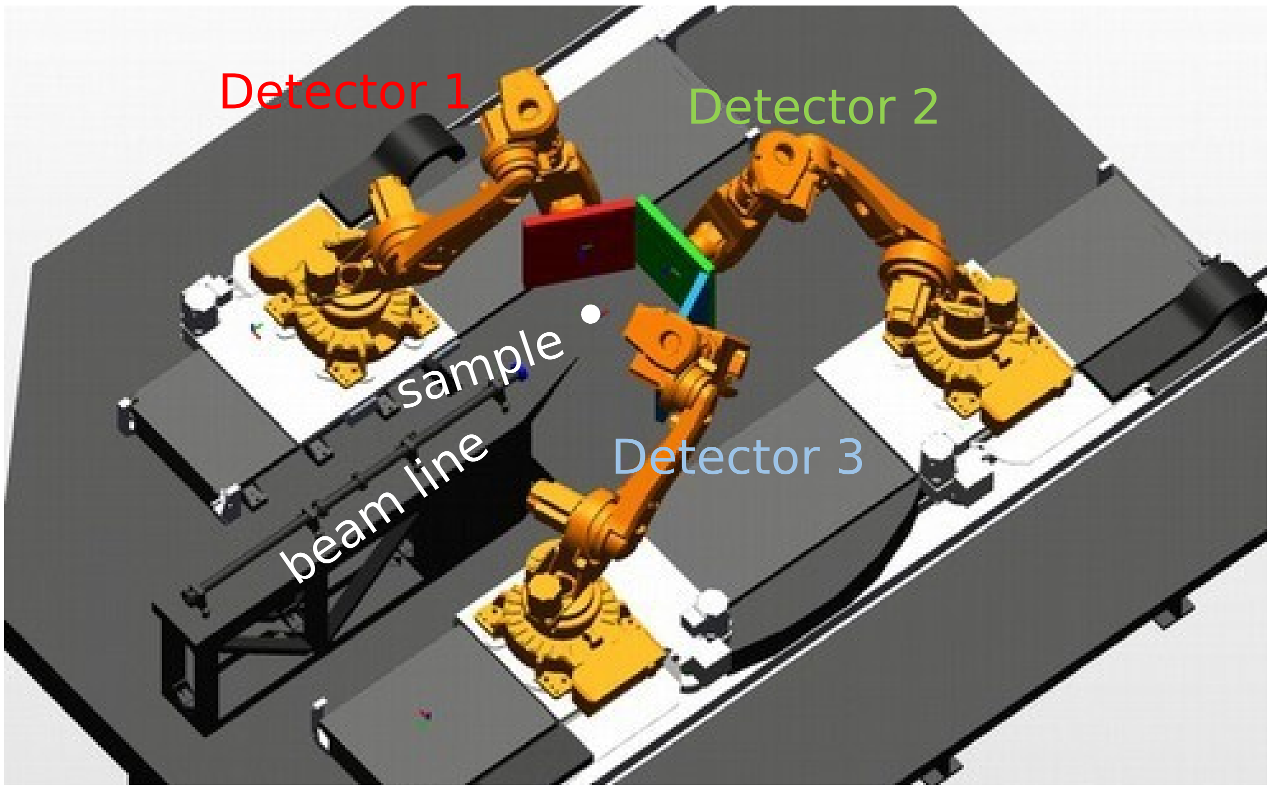
Michael Lupberger
CERN Fellow from May 2016
Detector Readout: VMM ASIC
integration, readout electronics,
firmware development, DAQ

Part time support by Hans Müller (retired CERN Staff) and Alexandru Rusu (CERN user)
Students involved: Lara Bartels, Freddy Fuentes, Manuel Guth, Yan Huang,
Matthias Machiels, Lucian Scharenberg, Muhammed Usman

We are part of the CERN Gaseous detector group within the EP-DT-DD section led by Leszek Ropelewski

Overview: The NMX demonstrator

No fixed geometry: Detectors on robotic arms



Detector Positioning System for ESS NMX, Final Design Report, J.-L. Ferrer

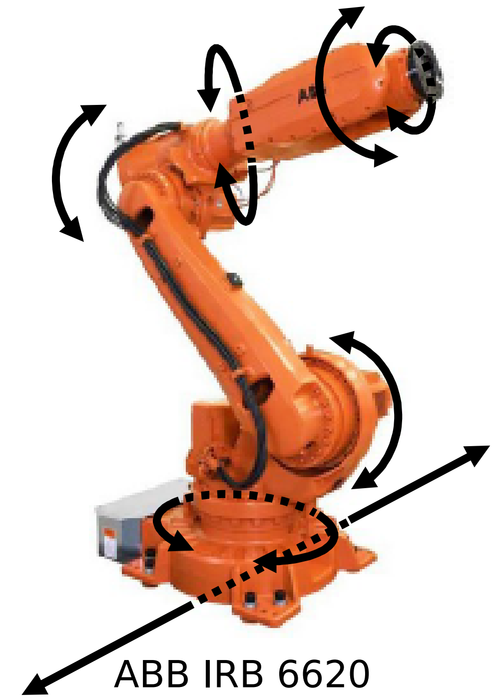
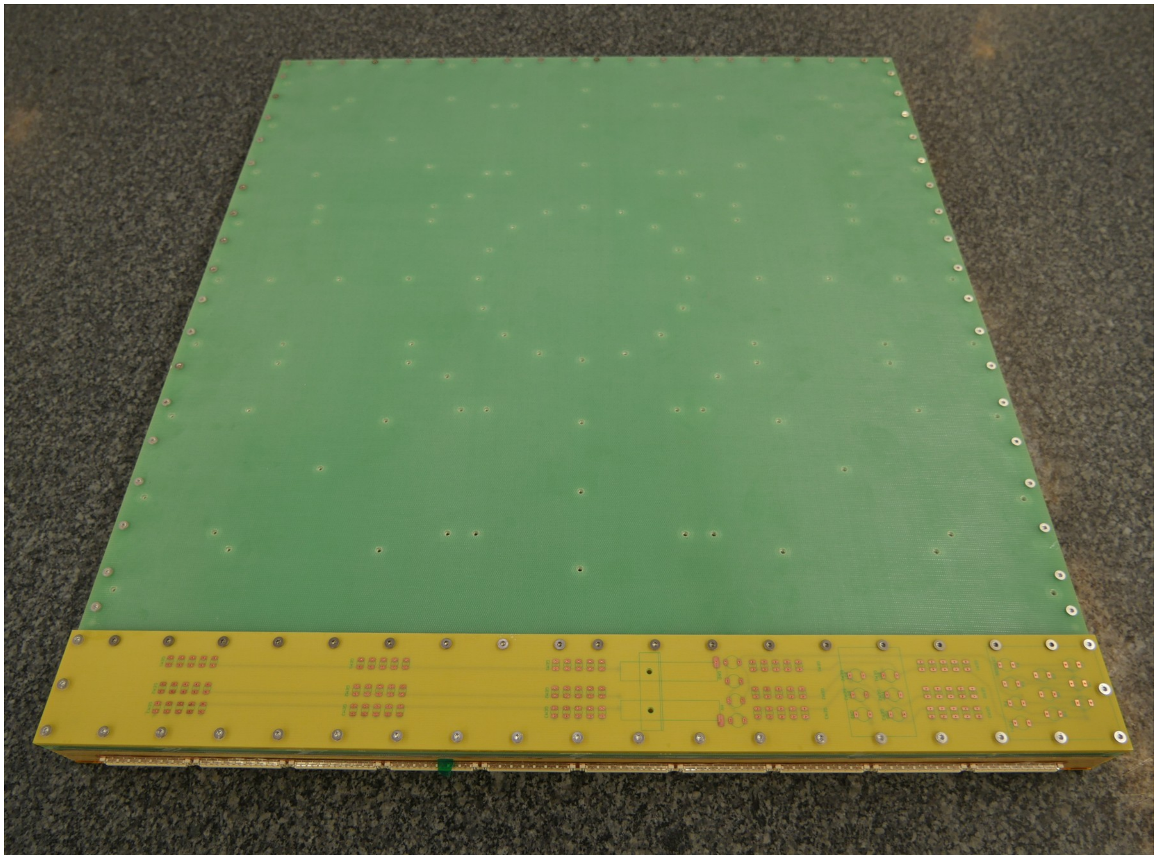
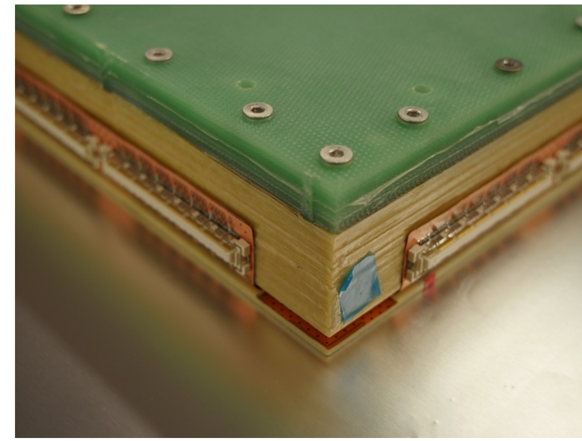


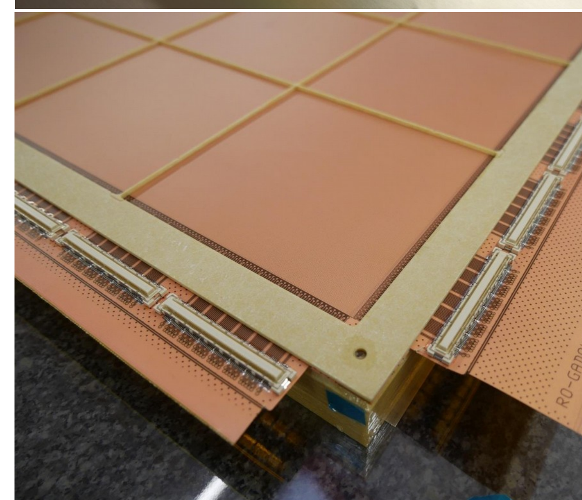
ABB IRB 6620
6 axes, 2.2 m reach
robotic arms on rails

Overview: The NMX demonstrator

ESS Detector Group Seminar 30.08.2018:
P. Thuiner, *NMX Zita - Building the the NMX detector prototype v0*,
https://indico.esss.lu.se/event/1100/

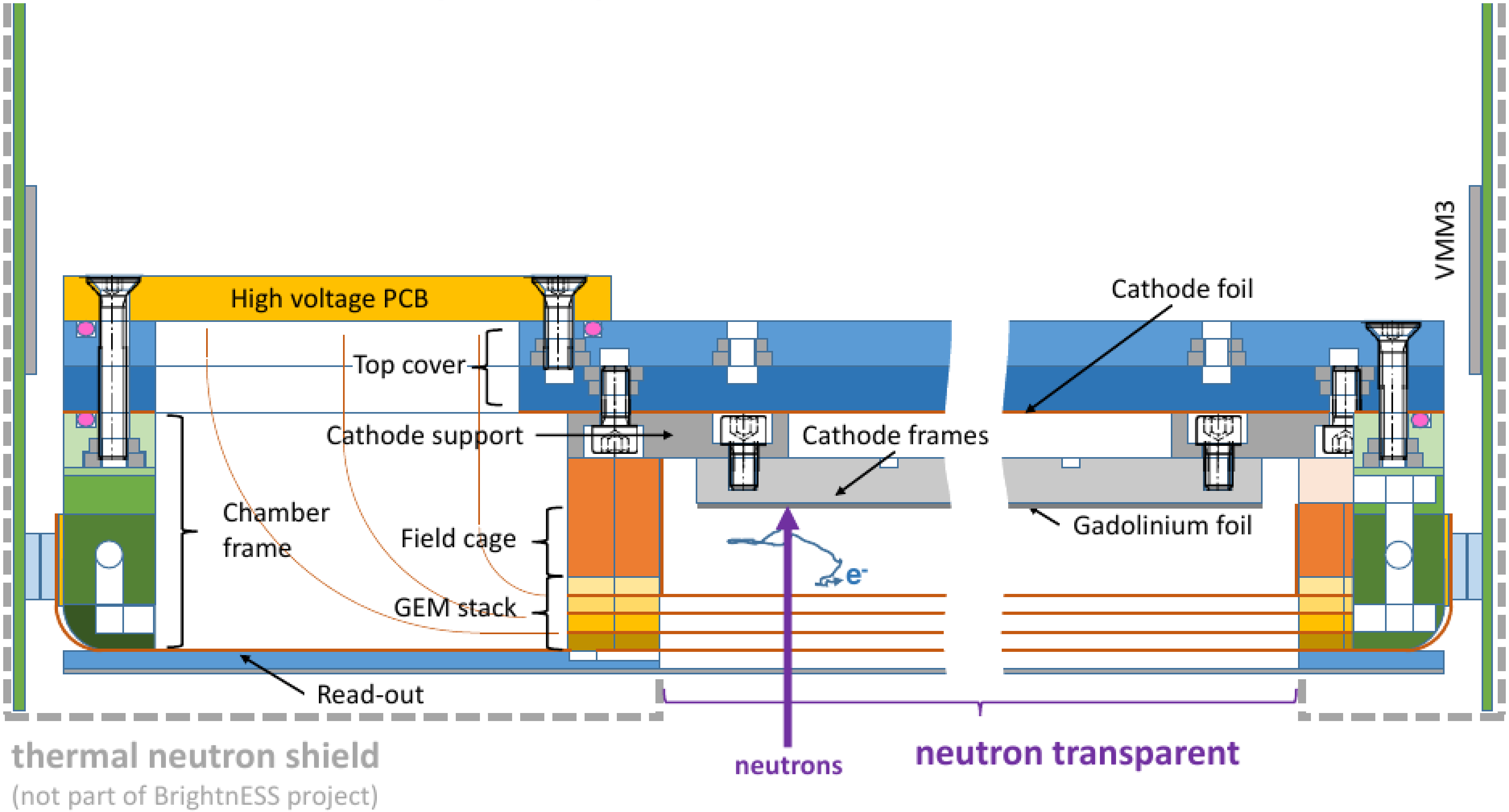






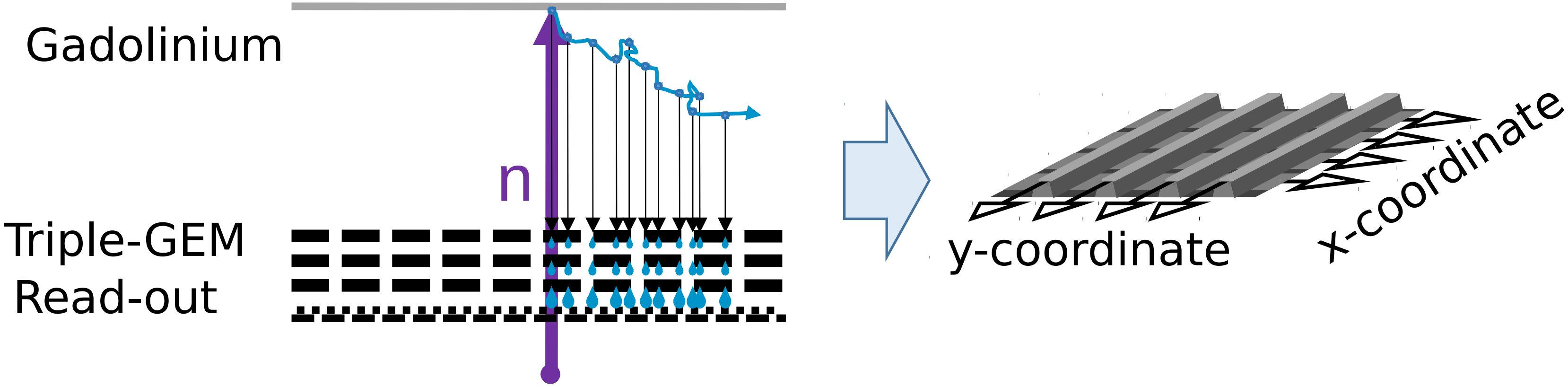
Overview: The NMX demonstrator

NMX demonstrator prototype v0 “Zita” - Cross-section



Electronics

The Scalable Readout System and VMM front-end ASIC



Anode strip pitch: 400 μm → position resolution

NMX prototype: 5120 strips with 4 kHz hits per strip
→ fast dense electronics needed to process charge signal: integrated circuit

μTPC requires time resolution O(ns) → high frequency clock

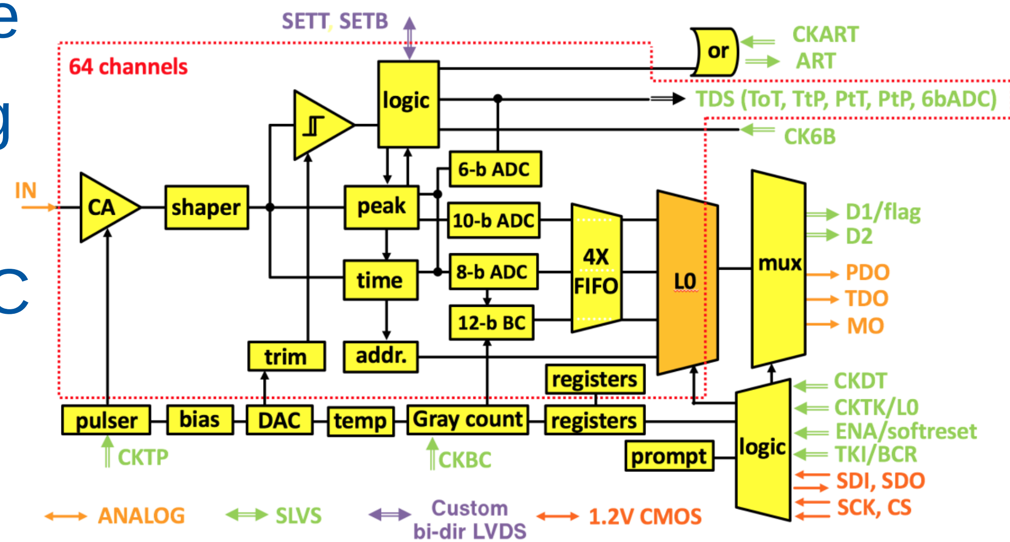
Robotic arms restrict number of cables from detector to back-end
→ digitise data on detector

⇒ Use high rate front-end ASIC with digitisation

Electronics

VMM front-end ASIC

- 130 nm CMOS technology
- 64 input channels, each w/ preamplifier, shaper, peak detector, several ADCs
- Pos. & neg. polarity sensitive
- Digital block w/ neighbouring logic, FIFO, multiplexer
- Adjustable gain 0.5-16 mV/fC
- Adjustable shaping time from 25 ns – 200 ns
- Input capacitance from few pF – 1 nF



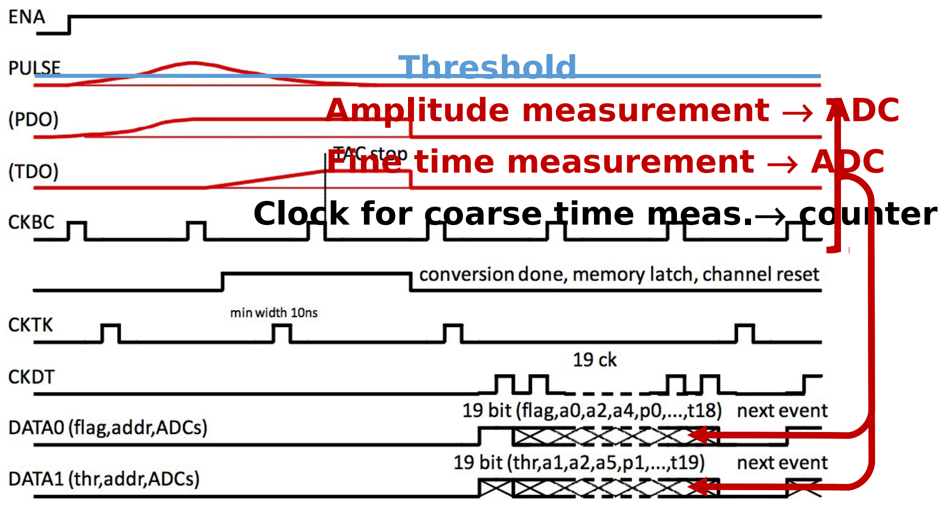
Electronics

VMM front-end ASIC

- Internal test pulser with adjustable amplitude
- Global threshold & adjustment per channel
- Self-triggered, zero suppressed
- 38 bit per hit

  (if input charge goes over threshold)

  1. Event flag (1 bit)
  2. Over threshold flag (1 bit)
  3. Channel number (6 bit)
  4. Signal amplitude (10 bit)
  5. Arrival time (20 bit)

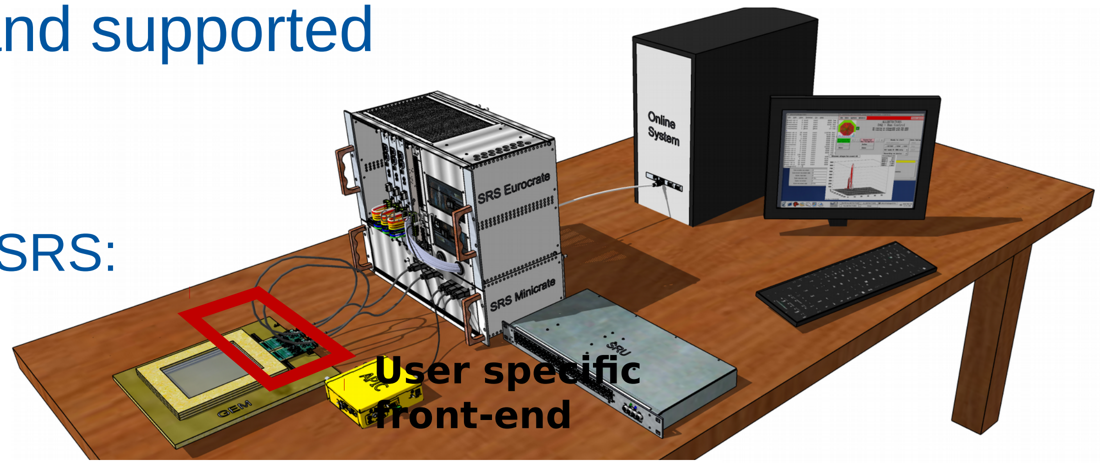


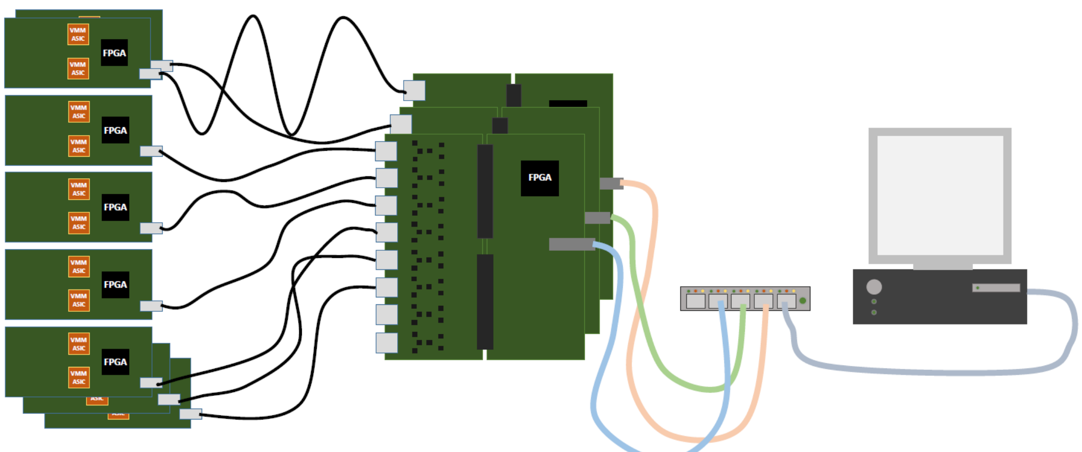
Electronics

Scalable Readout System (SRS)

A generic readout system for laboratory and detector instrumentation developed and supported by the RD51 Collaboration

Front-end ASICS implemented in SRS:
APV25, VFAT, Timepix, Beetle,
(Timepix3, VMM)





VMM Hybrid → HDMI cable → Adapter card + FEC → Ethernet → Switch →Ethernet → PC

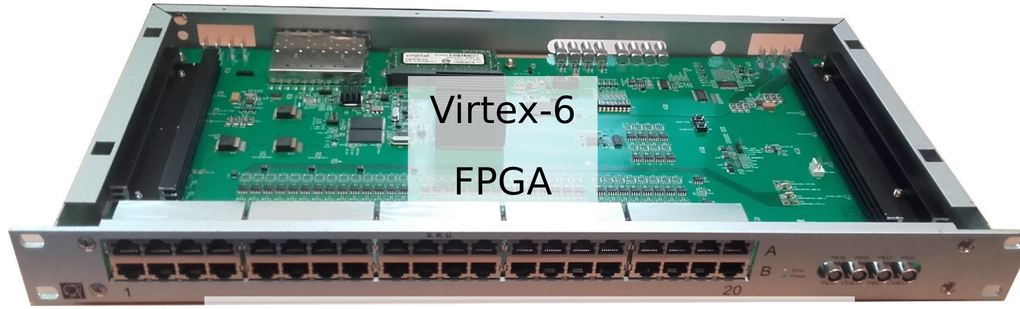
Electronics

Scalable Readout System (SRS)

Hardware components

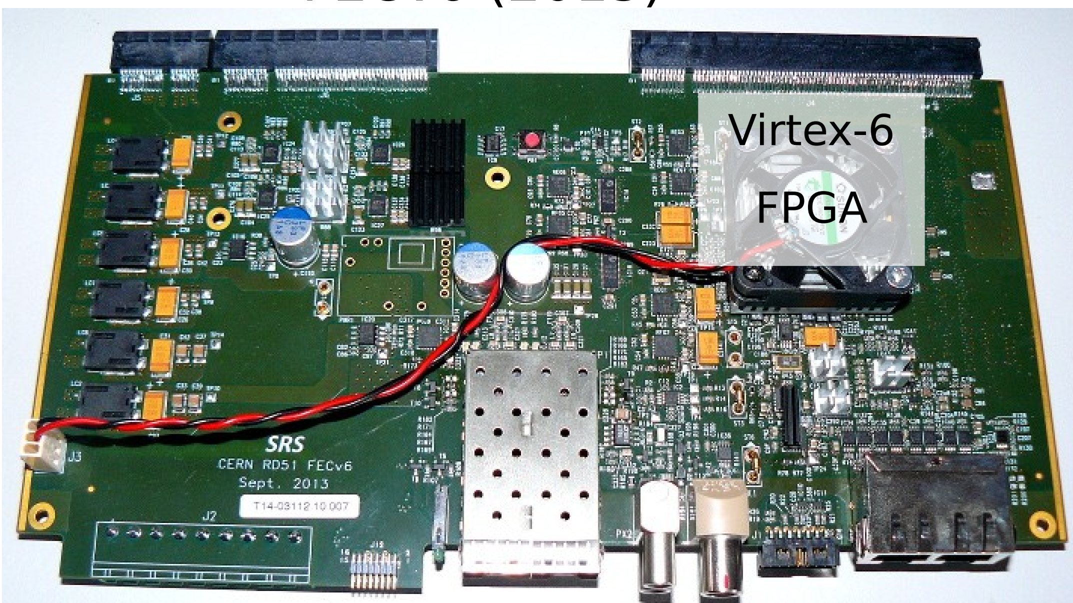
SRU

10 GbE SFP+



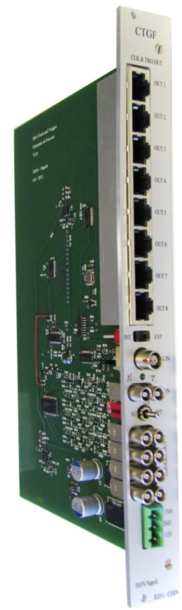
40x DDTC from FECs

FECv6 (2013)

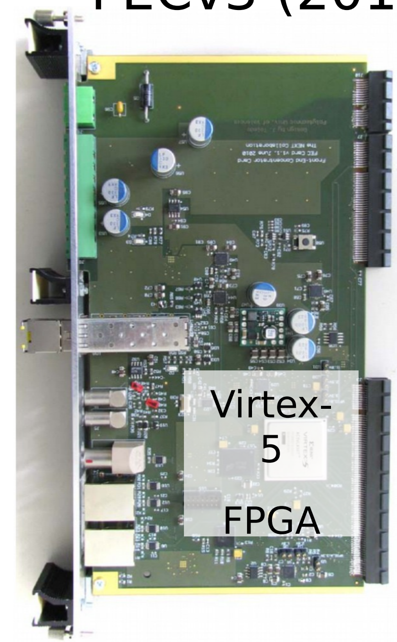


1 GbE or DDTC to SRU

CTGF v3

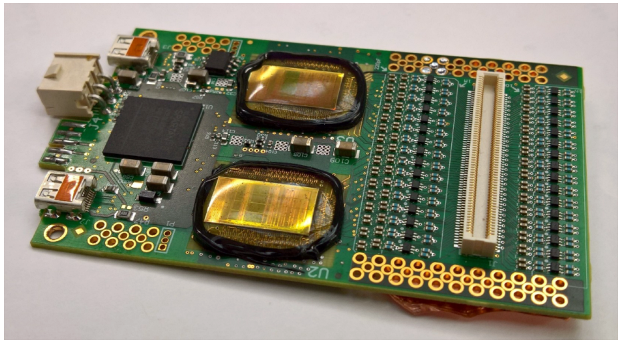


FECv3 (2010)



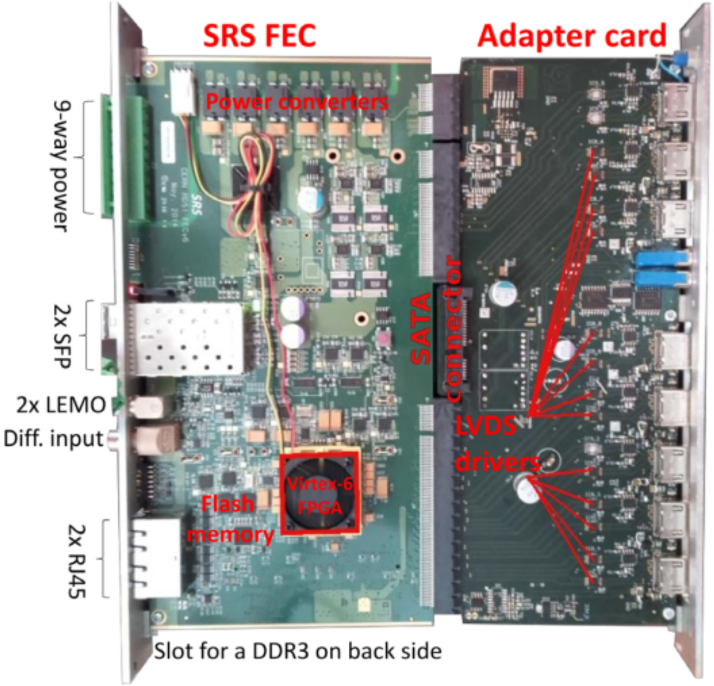
Electronics

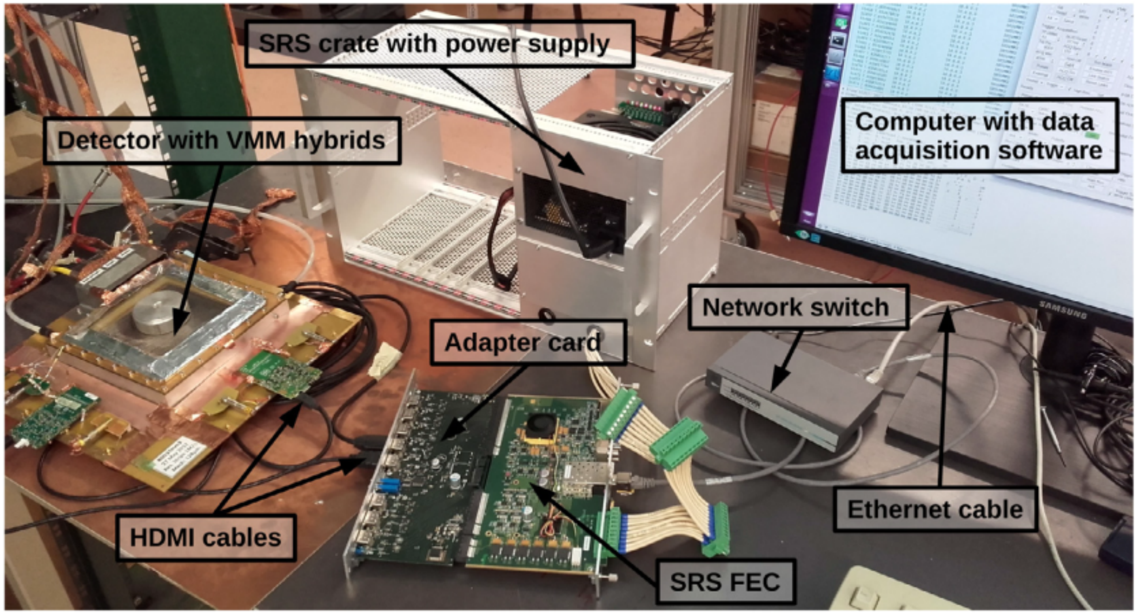
Scalable Readout System (SRS) - Status



Hardware components:

- SRS FEC: general SRS component → ✔
- Hybrid: 4 v3 (VMM3, VMM3a), 4 v4 (VMM3a, final), industrial test production started with 20 v4 (VMM3a) → ✔
- Adapter Card: 3 prototypes, final version design → 🔧





M. Lupberger et al., Implementation of the VMM ASIC in the Scalable Readout System, Nucl.Instrum.Meth. A903 (2018) 91-98

Electronics

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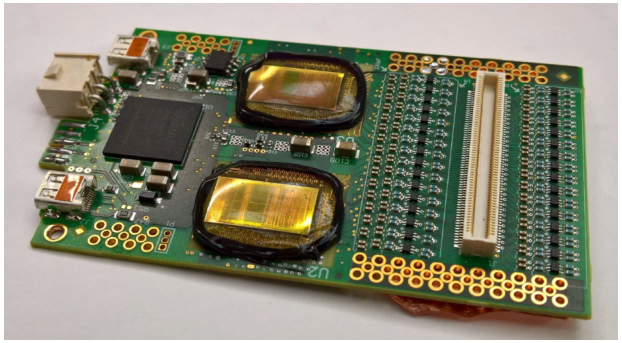

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Firmware:

- SRS FEC: basics working, improvements → ✔🔧
- Hybrid: basics working, improvements → ✔🔧

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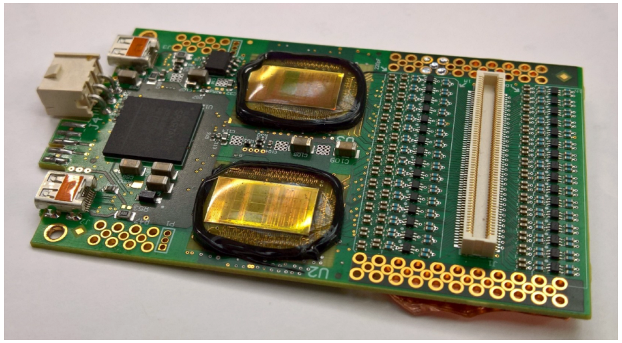

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Software:

- Slow control, online monitoring, DAQ working → ✔
- Redesign of standalone VMM DAQ ongoing→ 🔧

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Electronics

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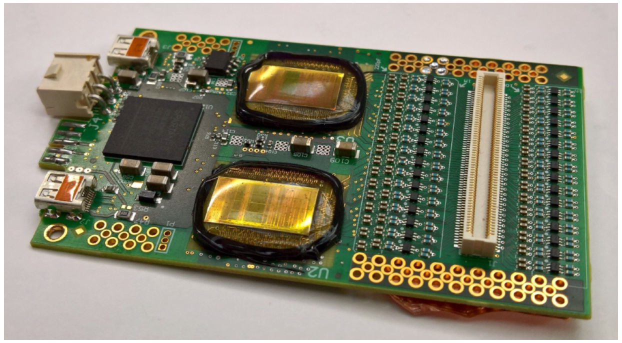

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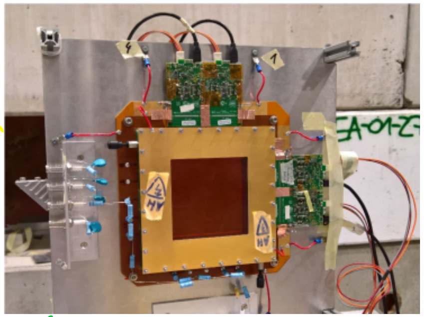

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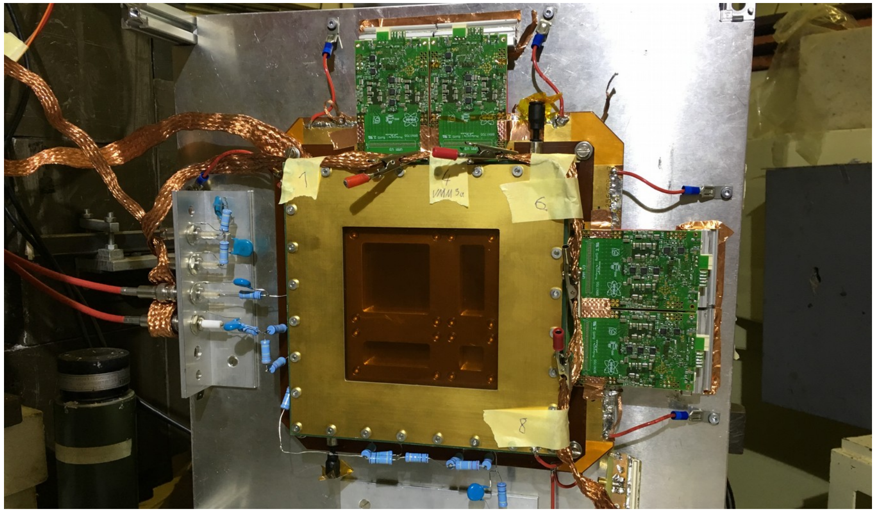
Integration

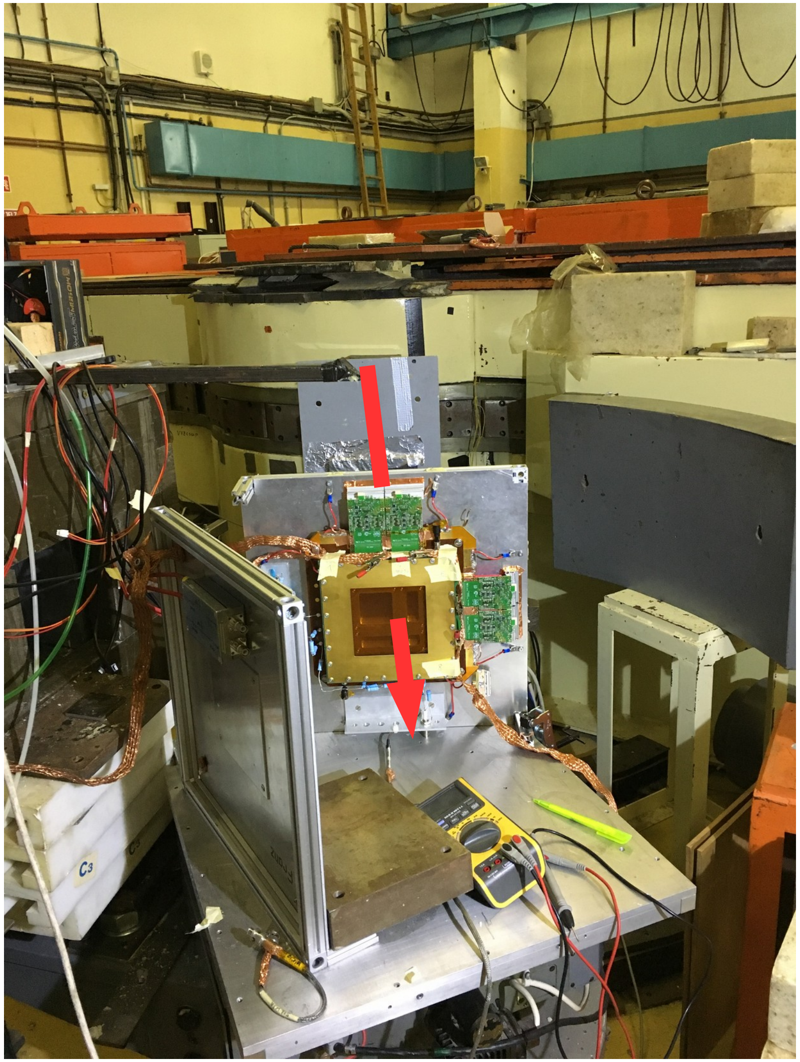
- Single FEC (4 hybrids) used at many test beams →✔
- Multi-FEC systems not tested→ 🔧

M. Lupberger et al., Implementation of the VMM ASIC in the Scalable Readout System, Nucl.Instrum.Meth. A903 (2018) 91-98

Test beam: Wigner Institute, Budapest July 2018

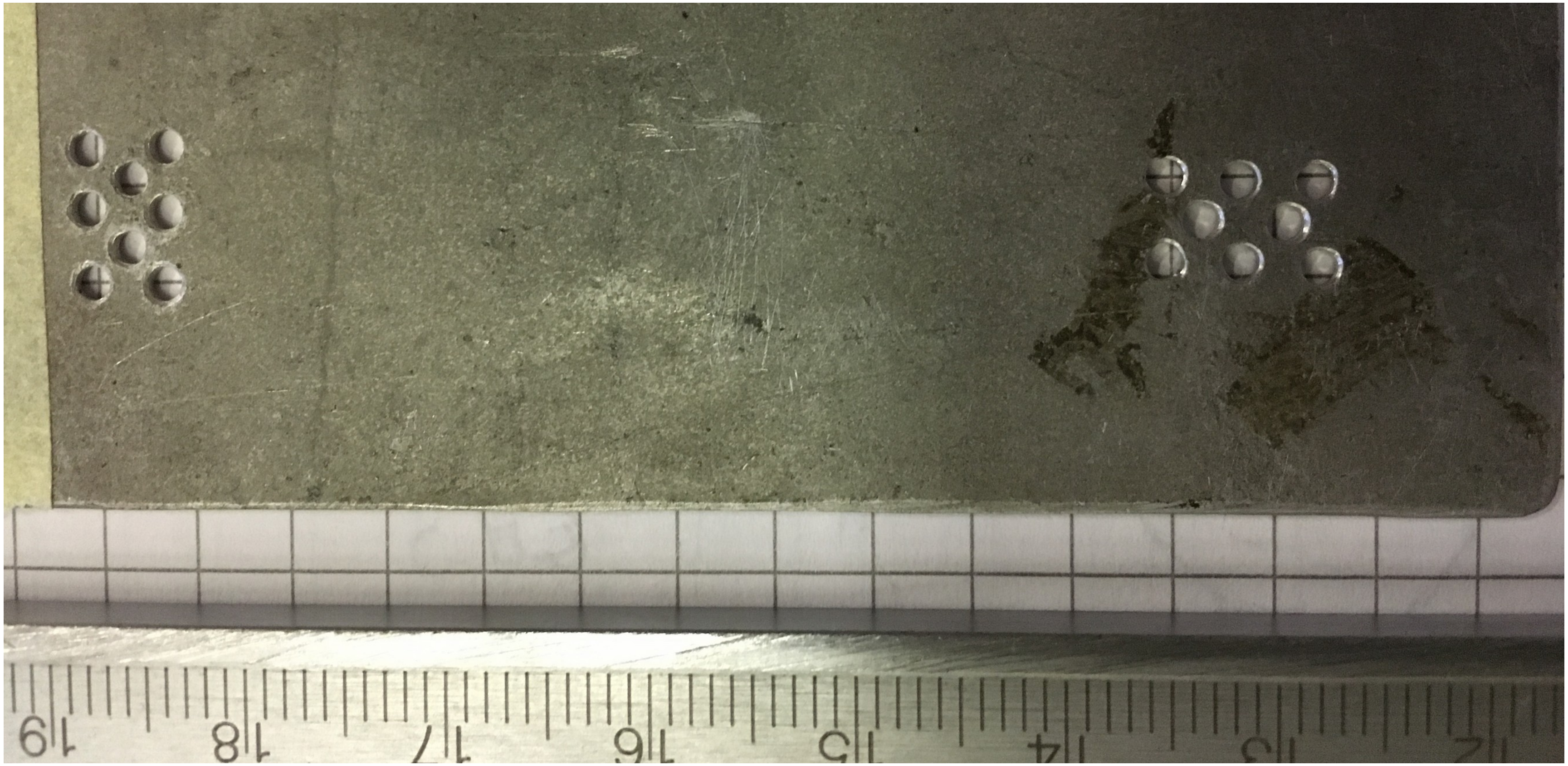
Small 10 cm x 10 cm version of NMX demonstrator with electronics





Test beam: Wigner Institute, Budapest July 2018

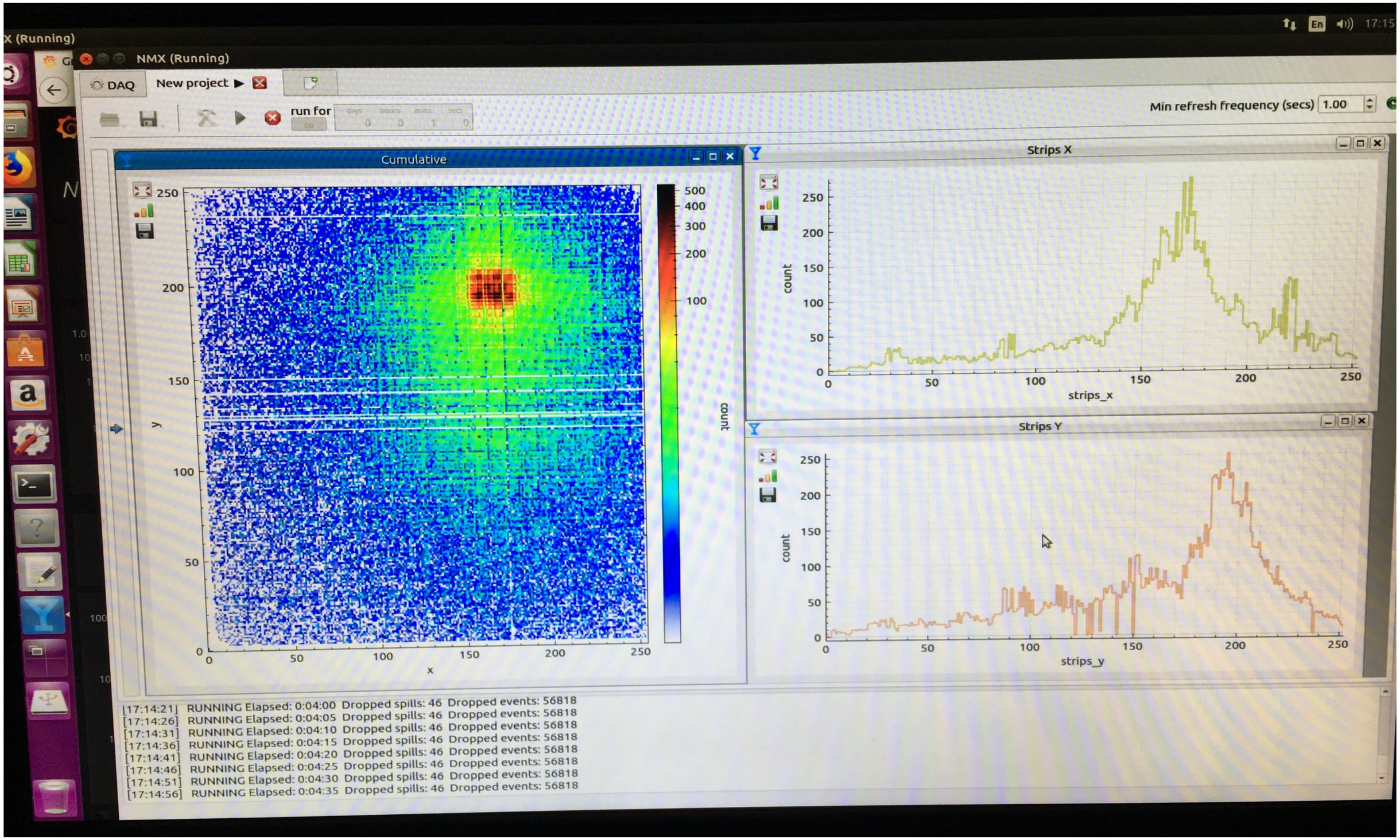
Measurement with cadmium mask 1.6 mm holes



Cd mask with holes of 1.6 mm diametre. The holes have a minimum separation (centre to centre) of about 2 mm horizontally, 1.6 mm vertically, and 1.3 mm diagonally.

Test beam: Wigner Institute, Budapest July 2018

Measurement with cadmium mask 1.6 mm holes - online



Online monitoring software (DAQUIRI from DMSC) screenshot of hit strips in the detector (neutron transmission throught Cd mask)

Test beam: Wigner Institute, Budapest July 2018

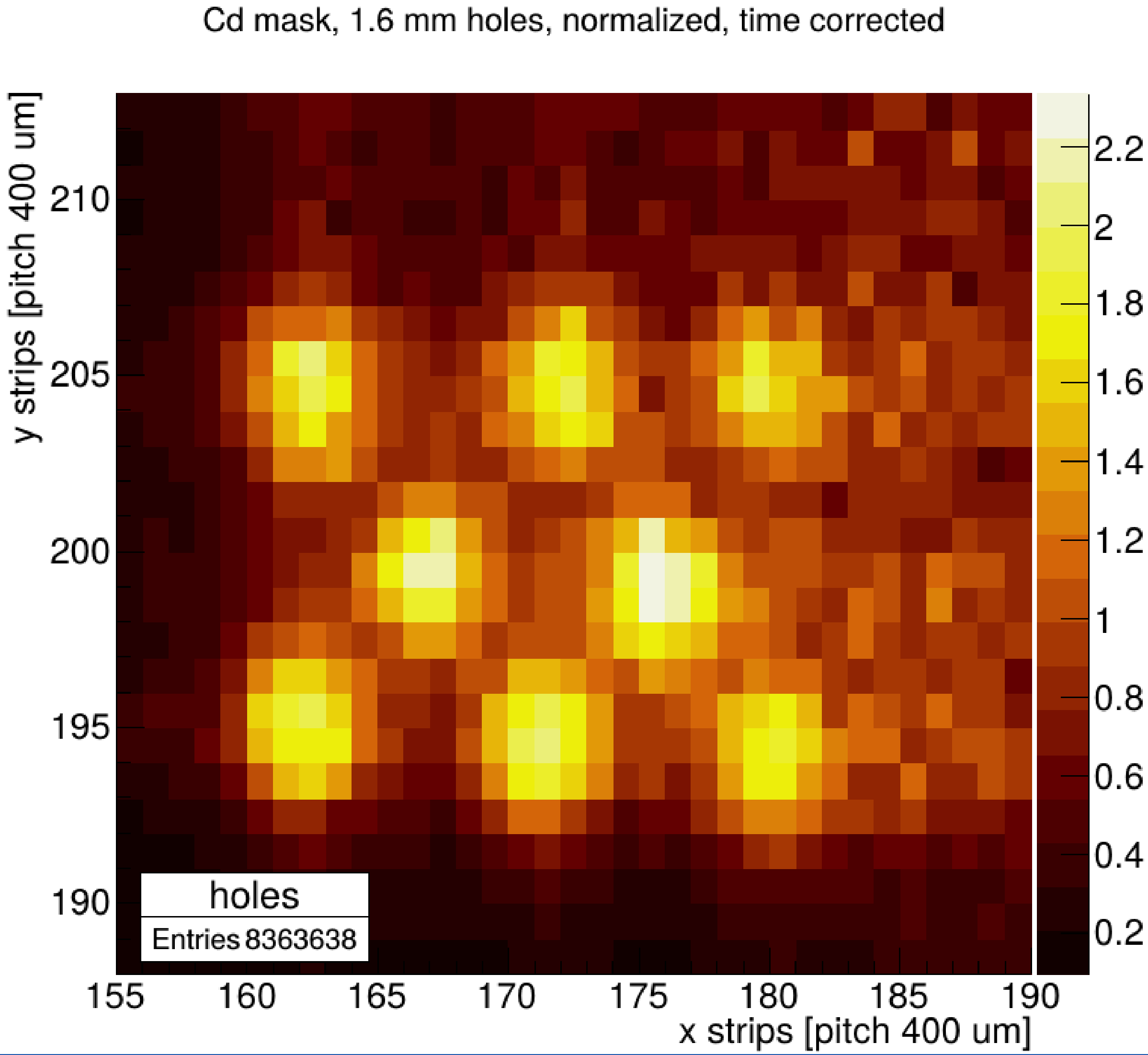
Measurement with cadmium mask 1.6 mm holes - reconstruction

Time correction:
Use time calibration
to correct VMM tdc

Clustering:
Assigning x to y hit
by matching time

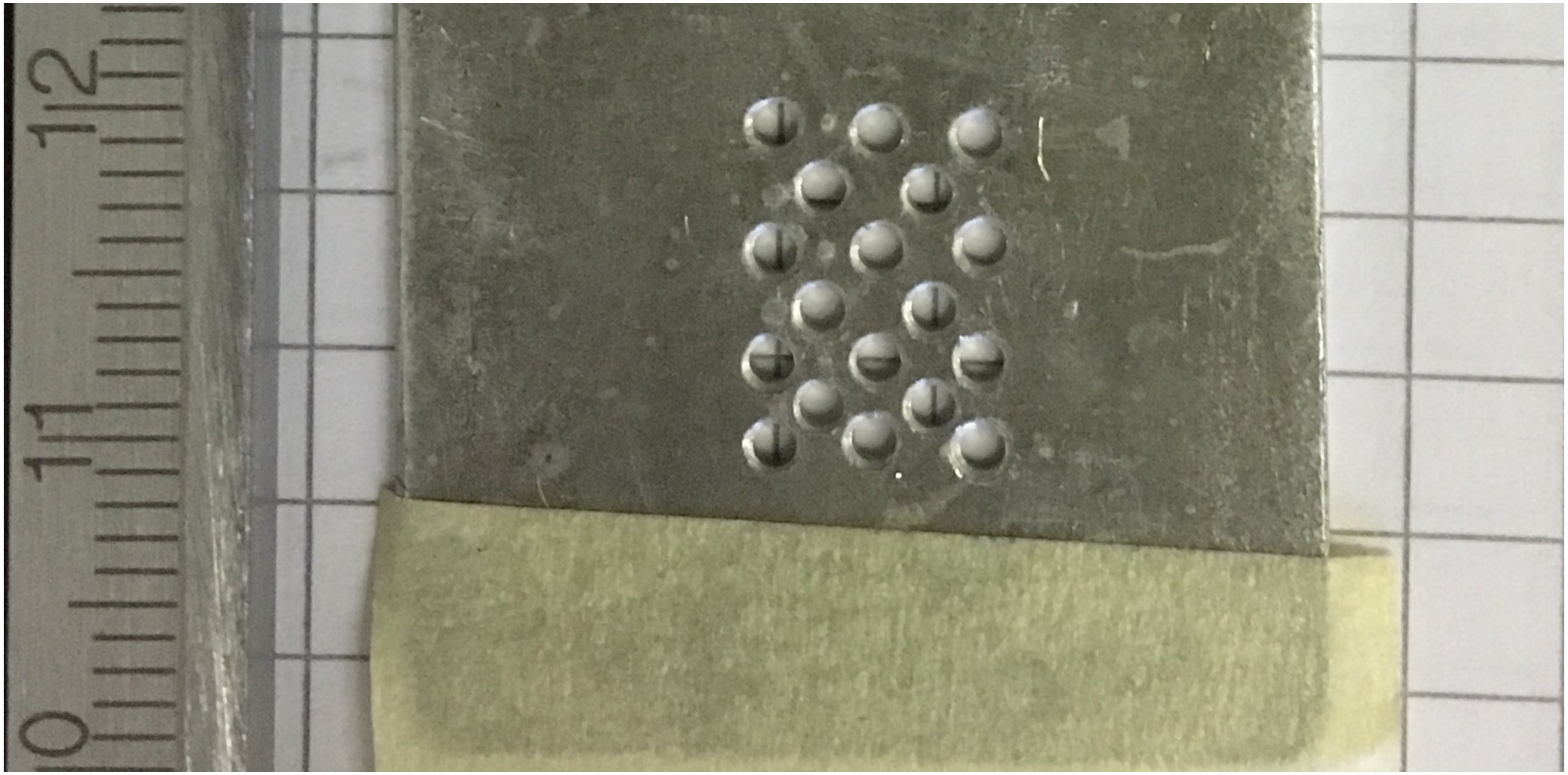
Neutron impact point:
Earliest hit position

Normalisation:
Account for beam profil



Test beam: Wigner Institute, Budapest July 2018

Measurement with cadmium mask 1.0 mm holes



Cd mask with holes of 1.0 mm diameter. The holes have a minimum separation (centre to centre) of about 2 mm horizontally, 1.6 mm vertically, and 1.3 mm diagonally.

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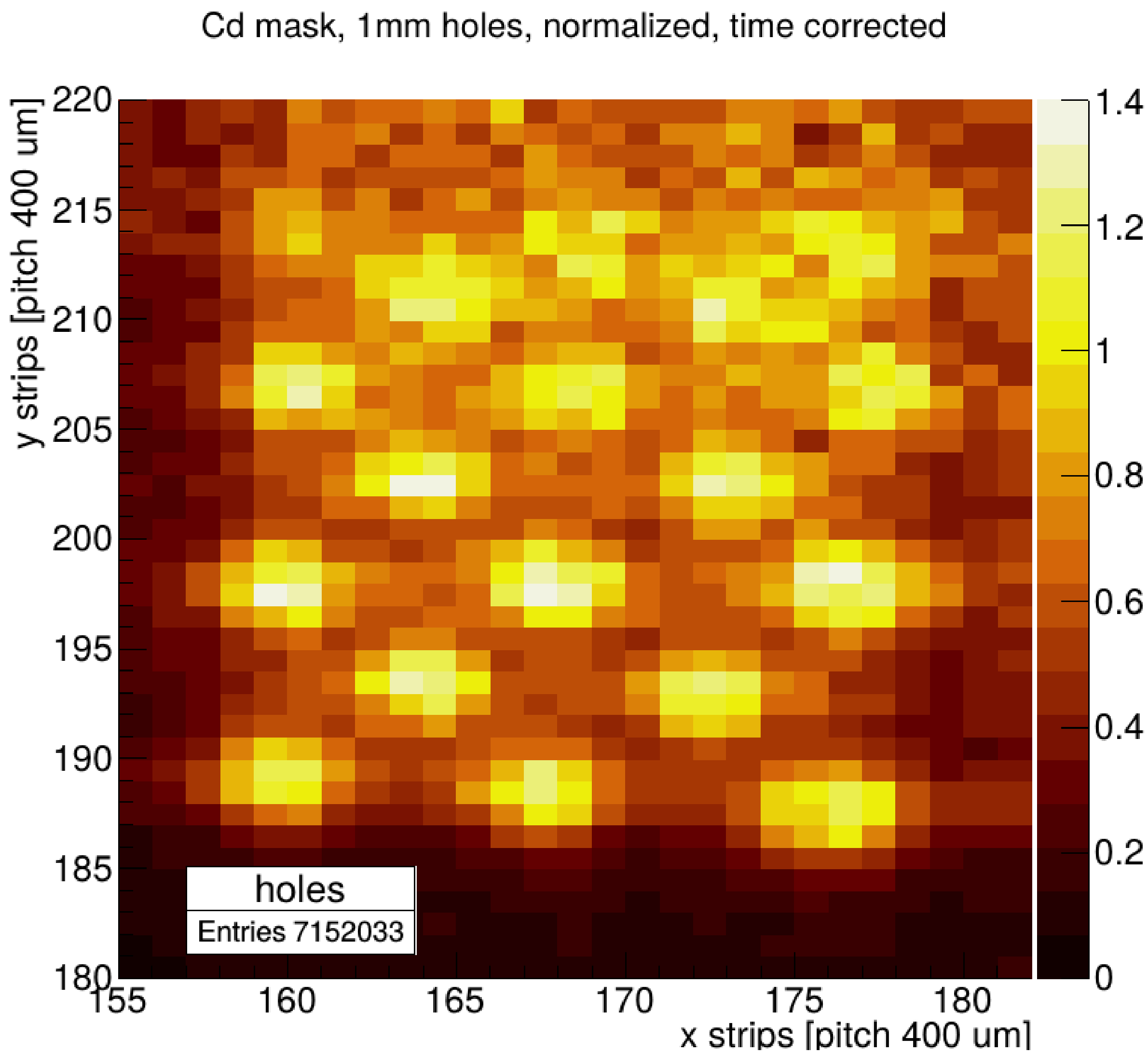

Test beam: Wigner Institute, Budapest July 2018

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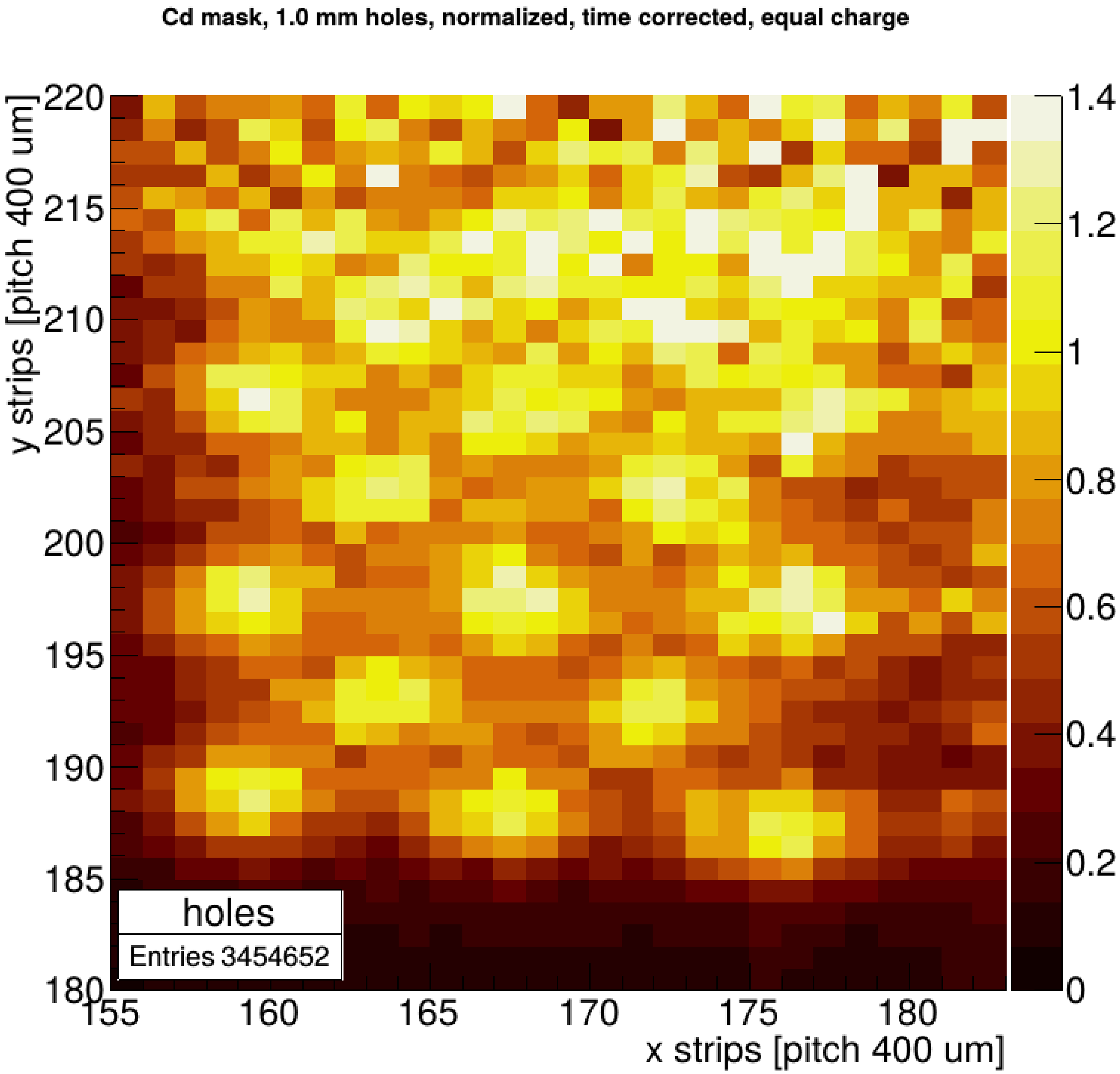

Improvement option equal Charge:

Only match x and y hit when they have about eqaual charge

Test beam: Wigner Institute, Budapest July 2018

Measurement with cadmium mask 1.0 mm holes - reconstruction

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Use time calibration
to correct VMM tdc

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Assigning x to y hit
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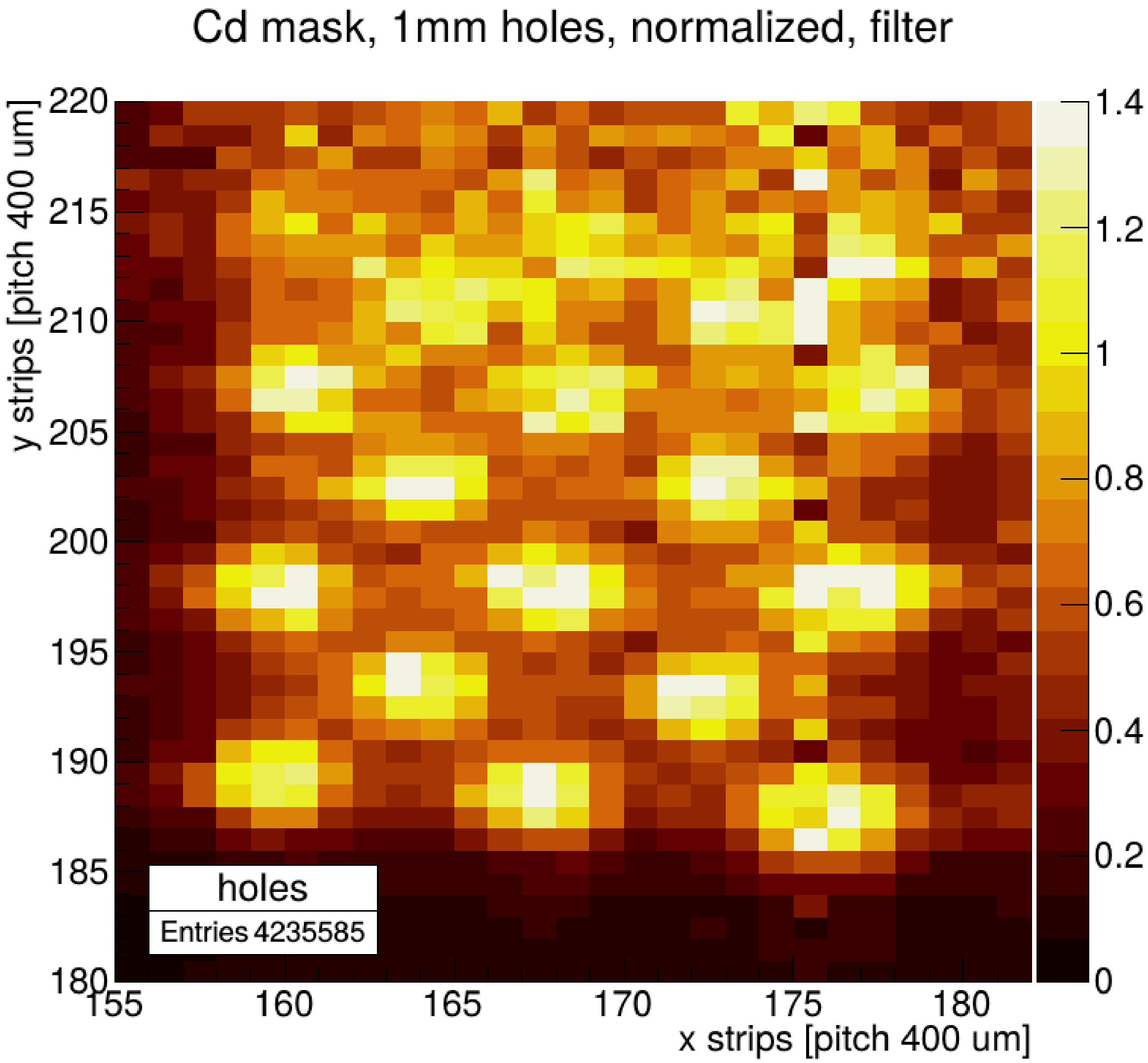
Earliest hit position

Normalisation:
Account for beam profil

Improvement option filter:
Remove not well defined clusters



Conclusion and outlook

BrightnESS has ended in August

- All Milestones and Deliverables have been achieved in time
- Demonstrator detector was constructed
- Readout electronics is available (in prototype state)
- Test beams with small scale prototypes have proven capabilities
  Detector meets requirements for NMX instrument

Next test beam with large demonstrator scheduled at ILL

- D16 beamline, first week of October
- 4 or even 8 hybrids, improved calibration

Transition/Preservation of know-how and technology

- Next iteration of detector design at ESS
- Electronics and software continued in CERN/RD51 and with DMSC

The end

During the BrightnESS project we had the chance to meet so many nice people and received a lot of support

- BNC: Márton Markó, Deszo Varga
- CERN: our whole group/department and especially Miranda van Stenis
- IFE: Sigurd Brattheim, Isabel Jansa Llamas, Marit Dalseth Riktor
- ESS: Steven Alcock, Giuseppe Aprigliano, Morten Jagd Christensen, Judith Freita Ramos, Richard Hall-Wilton, Scott Kolya, Esko Oksanen, Martin Shetty

Thanks!

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